

## ***ANNEX H: Methodology for Estimating Methane Emissions from Enteric Fermentation***

The following steps were used to estimate methane emissions from enteric fermentation in livestock.

### **Step 1: Collect Livestock Population Data**

All livestock population data, except for horses, were taken from U.S. Department of Agriculture (USDA) statistical reports. For each animal category, the USDA publishes monthly, annual, and multi-year livestock population and production estimates. Multi-year reports include revision to earlier published data. Recent reports were obtained from the USDA Economics and Statistics System website, at <http://www.mannlib.cornell.edu/usda/>, while historical data were downloaded from the USDA-National Agricultural Statistics Service (NASS) website at <http://www.usda.gov/nass/pubs/dataprd1.htm>.

The Food and Agriculture Organization (FAO) publish horse population data. These data were accessed from the FAOSTAT database at <http://apps.fao.org/>. Table H-1 summarizes the published population data by animal type.

### **Step 2: Estimate Emission Factors for Dairy Cows**

Regional dairy cow emission factors from the 1993 Report to Congress (EPA 1993) were used as the starting point for the analysis. These emission factors were used to calibrate a model of methane emissions from dairy cows. The model applies revised regional emission factors that reflect changes in milk production per cow over time. Increases in milk production per cow, in theory, require increases in feed intake, which lead to higher methane emissions per cow. Table H-2 presents the emission factors per head by region used for dairy cows and milk production. The regional definitions are from EPA (1993).

### **Step 3: Estimate Methane Emissions from Dairy Cattle**

Dairy cow emissions for each state were estimated by multiplying the published state populations by the regional emission factors, as calculated in Step 2. Dairy replacement emissions were estimated by multiplying national replacement populations by a national emission factor. The USDA reported the number of replacements 12 to 24 months old as “milk heifers.” It is assumed that the number of dairy cow replacements 0 to 12 months old was equivalent to the number 12 to 24 months old replacements.

### **Step 4: Estimate Methane Emissions from Beef Cattle**

Beef cattle methane emissions were estimated by multiplying published cattle populations by emission factors. Emissions from beef cows and replacements were estimated using state population data and regional emission developed by EPA (1993), as shown in Table H-3. Emissions from slaughter cattle and bulls were estimated using national data and emission factors. The emission factors for slaughter animals represent their entire life, from birth to slaughter. Consequently, the emission factors were multiplied by the national data on total steer and heifer slaughters rather than live populations of calves, heifers, and steers grown for slaughter. Slaughter population numbers were taken from USDA datasets. The Weanling and Yearling mix was unchanged from earlier estimates derived from discussions with industry representatives.

### **Step 5: Estimate Methane Emissions from Other Livestock**

Methane emissions from sheep, goats, swine, and horses were estimated by multiplying published national population estimates by the national emission factor for each year.

A summary of emissions is provided in Table H-4. Emission factors, national average or regional, are shown by animal type in Table H-5.

Table H-1: Livestock Population (Thousand Head)

<b>Animal Type</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>
<b>Dairy</b>									
Cows	10,007	9,883	9,714	9,679	9,504	9,491	9,410	9,309	9,200
Replacements 0-12	4,135	4,097	4,116	4,088	4,062	4,011	3,895	3,829	3,793
Replacements 12-24	4,135	4,097	4,116	4,088	4,062	4,011	3,895	3,829	3,793
<b>Beef</b>									
Cows	32,677	32,960	33,453	34,132	35,101	35,645	35,509	34,629	34,143
Replacements 0-12	5,141	5,321	5,621	5,896	6,132	6,076	5,844	5,671	5,282
Replacements 12-24	5,141	5,321	5,621	5,896	6,132	6,076	5,844	5,671	5,282
Slaughter-Weanlings	5,199	5,160	5,150	5,198	5,408	5,612	5,580	5,692	5,666
Slaughter-Yearlings	20,794	20,639	20,600	20,794	21,632	22,450	22,322	22,770	22,663
Bulls	2,180	2,198	2,220	2,239	2,306	2,392	2,392	2,325	2,235
<b>Other</b>									
Sheep	11,358	11,174	10,797	10,201	9,825	8,982	8,458	8,015	7,817
Goats	2,545	2,475	2,645	2,605	2,605	2,495	2,545	2,295	2,045
Horses	5,650	5,650	5,850	5,900	6,000	6,000	6,050	6,150	6,150
Hogs	53,941	56,478	58,532	58,016	59,951	58,899	56,220	58,728	62,043

Table H-2: Dairy Cow CH<sub>4</sub> Emission Factors and Milk Production Per Cow

<b>Region</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>
<b>Dairy Cow Emission Factors (kg/head)</b>									
North Atlantic	116.2	118.5	121.3	121.0	121.7	124.3	124.8	125.8	125.8
South Atlantic	127.7	128.7	132.3	132.2	134.2	132.9	133.6	136.5	136.5
North Central	105.0	105.7	107.8	107.6	109.2	110.9	110.5	112.2	111.8
South Central	116.2	116.1	117.9	119.0	121.2	121.7	121.4	121.5	120.5
West	130.4	129.6	132.7	132.6	137.9	135.7	135.1	136.9	139.4
<b>Milk Production (kg/year)</b>									
North Atlantic	6,574	6,811	7,090	7,055	7,134	7,391	7,439	7,546	7,693
South Atlantic	6,214	6,300	6,622	6,608	6,783	6,667	6,730	6,986	6,847
North Central	6,334	6,413	6,640	6,623	6,791	6,980	6,936	7,123	7,441
South Central	5,696	5,687	5,849	5,951	6,160	6,206	6,180	6,182	6,204
West	8,339	8,255	8,573	8,559	9,107	8,884	8,822	8,999	8,991

Table H-3: CH<sub>4</sub> Emission Factors Beef Cows and Replacements (kg/Head/Year)

<b>Region</b>	<b>Replacements (0-12)</b>	<b>Replacements (12-24)</b>	<b>Mature Cows</b>
North Atlantic	19.2	63.8	61.5
South Atlantic	22.7	67.5	70.0
North Central	20.4	60.8	59.5
South Central	23.6	67.7	70.9
West	22.7	64.8	69.1

Table H-4: Methane Emissions from Livestock Enteric Fermentation (Gg)

<b>Animal Type</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>
<b>Dairy</b>	<b>1,474</b>	<b>1,465</b>	<b>1,473</b>	<b>1,468</b>	<b>1,471</b>	<b>1,473</b>	<b>1,454</b>	<b>1,453</b>	<b>1,443</b>
Cows	1,150	1,144	1,150	1,148	1,152	1,159	1,149	1,153	1,146
Replacements 0-12	81	80	81	80	80	79	76	75	74
Replacements 12-24	243	241	242	240	239	236	229	225	223
<b>Beef</b>	<b>3,951</b>	<b>3,979</b>	<b>4,039</b>	<b>4,120</b>	<b>4,256</b>	<b>4,340</b>	<b>4,305</b>	<b>4,246</b>	<b>4,165</b>
Cows	2,181	2,199	2,233	2,278	2,342	2,380	2,371	2,310	2,279
Replacements 0-12	115	119	125	132	137	136	130	126	118
Replacements 12-24	334	346	365	383	398	395	380	368	342
Slaughter-Weanlings	120	119	119	120	125	130	129	131	131
Slaughter-Yearlings	984	976	974	984	1,023	1,062	1,056	1,077	1,072
Bulls	218	220	222	224	231	239	239	233	223
<b>Other</b>	<b>286</b>	<b>288</b>	<b>293</b>	<b>288</b>	<b>290</b>	<b>281</b>	<b>274</b>	<b>274</b>	<b>277</b>
Sheep	91	89	86	82	79	72	68	64	63
Goats	13	12	13	13	13	12	13	11	10
Horses	102	102	105	106	108	108	109	111	111
Hogs	81	85	88	87	90	88	84	88	93
<b>Total</b>	<b>5,712</b>	<b>5,732</b>	<b>5,804</b>	<b>5,876</b>	<b>6,016</b>	<b>6,094</b>	<b>6,032</b>	<b>5,973</b>	<b>5,885</b>

Table H-5: Enteric Fermentation CH<sub>4</sub> Emission Factors

<b>Animal Type</b>	<b>kg/head/year</b>
<b>Dairy</b>	
Cows	regional
Replacements 0-12	19.6
Replacements 12-24	58.8
<b>Beef</b>	
Cows	regional
Replacements 0-12	regional
Replacements 12-24	regional
Slaughter-Weanlings	23.1
Slaughter-Yearlings	47.3
Bulls	100.0
<b>Other</b>	
Sheep	8.0
Goats	5.0
Horses	18.0
Hogs	1.5